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Pigeons, Humans, and the Monty Hall Dilemma

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Abstract

The Monty Hall Dilemma is a probability puzzle that is notorious for eliciting suboptimal decisions from humans. A participant is given a choice from among three doors, one of which conceals a valuable prize. After an initial selection, one of the remaining, nonwinning doors is opened, and the participant is given a chance to switch to the other unopened door. The probability of winning is higher if the participant switches. Pigeons maximize their wins by switching on virtually all trials of a Monty Hall Dilemma analogue, whereas humans utilize a suboptimal strategy involving probability matching. Possible reasons for the difference between these two species' performance are considered.

Keywords

Monty Hall Dilemma, pigeons, optimality, heuristics, probability matching

People are often surprised to learn that much of what we perceive and remember is erroneous. That is, normal cognitive functioning is subject to a variety of unexpected cognitive illusions. For example, under some circumstances, people consistently overestimate vertical distances (Jackson & Cormack, 2007). People can also be made to remember in great detail events that did not happen at all (Frenda, Nichols, & Loftus, 2011). In each case, the failure of a cognitive process reveals something about how that process works. Overestimation of vertical distances judged from above, but not from below, is adaptive because it reduces the likelihood of dangerous falls. Similarly, memory illusions are a by-product of the reconstructive nature of memory.

Persistent Cognitive Error in Performance on the Monty Hall Dilemma

Rather than being limited to memory and perception, errors may occur in any domain of cognition. One example of a pervasive error in mathematical reasoning is exemplified by the Monty Hall Dilemma. The dilemma is anecdotally based on the classic television game show *Let's Make a Deal*, hosted by Monty Hall. In the dilemma, a lucky contestant is offered a choice among three doors and told that one door conceals a desirable prize, such as a new sports car. The two remaining doors each contain a valueless gag prize, such as a mangy goat. After the contestant selects a door, Monty Hall reveals what is behind another door, being careful to open neither the door chosen by the contestant nor the door that contains the prize. The contestant is then given an opportunity to switch to the remaining unopened door. Most individuals decline, despite the fact that switching would double their chance of winning.

The following is one explanation for why switching is the better strategy. The probability that a participant will randomly select the door with the prize on the first guess is one in three, because there is one prize and three possible locations. If the initial selection is the winning door, then after the host reveals one goat, it follows that the second goat must be behind the remaining unselected door. Thus, on one-third of all trials, staying wins and switching loses. In contrast, the probability that a contestant will not choose the door with the prize on the first guess is two in three. If the contestant's chosen door conceals one goat, and the other goat has been revealed, then the remaining door must conceal the prize. Thus, two-thirds of the time, switching wins and staying loses.

Because the dilemma is usually articulated as a single trial, responses reflect people's initial understanding of the probabilities involved, but not necessarily their ability to learn. In order to determine whether people could learn to switch, Granberg and Brown (1995) had participants complete 50 trials of the Monty Hall Dilemma and receive feedback after each trial. Participants became more likely to switch, but they eventually reached a plateau, switching on only about two-thirds of the trials. This pattern indicates that the suboptimal tendency to stay is persistent, and although it can be reduced, does not go away entirely. Furthermore, the tendency to stay is

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a cross-cultural phenomenon: Granberg (1999) found that participants from Brazil, China, Sweden, and the United States exhibited the same tendency. Even the prize-winning Hungarian mathematician Paul Erdös initially failed to embrace the correct solution, falling prey to the same cognitive illusion that nonmathematicians do (Hoffman, 1998).

Comparative Data for Performance on the Monty Hall Dilemma

Humans may for some reason be especially ill-suited to solving the Monty Hall Dilemma. Herbranson and Schroeder (2010) conducted a comparative study of humans and pigeons, presenting each with a task that was structurally equivalent to the dilemma. In an operant chamber, the pigeons were presented with three response keys, corresponding to the three doors, that were illuminated with white light at the beginning of each trial. Prior to each trial, one of the three keys was randomly designated as the location of the prize, but was in no way visually distinct from the others. A single peck from the pigeon locked in an initial choice, and then one key was deactivated according to the standard constraints of the Monty Hall Dilemma: It could not be the key that the pigeon had pecked, nor could it be the prize location. Following a brief delay, the two remaining keys were illuminated again, and a second peck produced either reinforcement (if the peck was to the prize key) or a time-out before the next trial (if it was not to the prize key). Pigeons completed up to 100 trials per day over 30 days (see Fig. 1). Human participants completed 200 trials using a computer display and touch-screen monitor. Following each trial, rather than receiving grain or a time-out, the participants were presented with visual feedback (the word "win" or "lose"). Humans were not given a Monty Hall Dilemma story, and care was taken to avoid terminology commonly associated with the Monty Hall Dilemma (e.g., the words "switch," "stay," and "goat"). They were told only that they should try to maximize their number of wins.

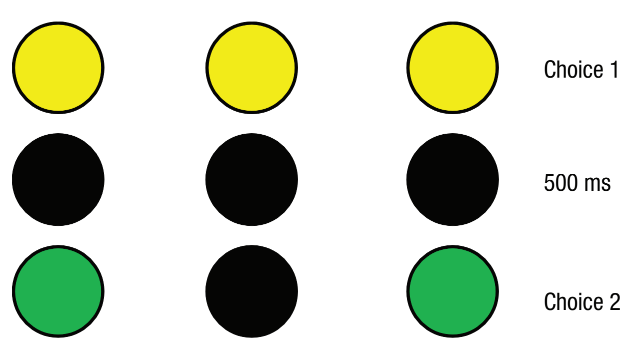

Fig. 1. Schematic representation of a trial from the experiment conducted by Herbranson and Schroeder (2010) on pigeons. At the beginning of a trial, all three keys were illuminated with white light (top row), and the pigeon pecked one key to lock in an initial choice. Following a 500-ms delay (middle row) during which all keys were dark, the pigeon made a second choice between two of the keys, which were now illuminated with green light (bottom row). The third key was left dark and could not be the one that had been initially pecked or the one that contained the "prize" (a reward of grain).

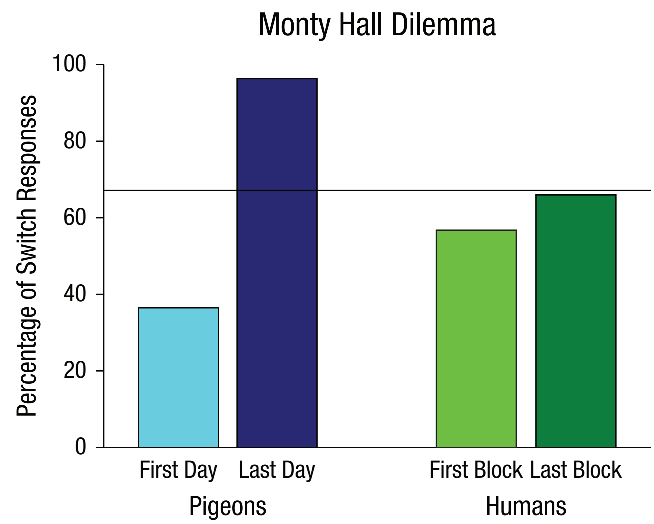

Fig. 2. Percentage of switch responses by pigeons and humans at the beginning and end of the experiment by Herbranson and Schroeder (2010). The line in the graph is at 67%, the probability of winning with a switch response. The optimal strategy is to switch on all trials.

Figure 2 shows how pigeons and humans responded at the beginning and at the end of the experiment. Pigeons began with a tendency to stay, but they eventually settled on a strategy of switching on virtually all trials. Human participants quickly developed a tendency to switch on about two-thirds of trials. The humans completed fewer trials than the pigeons did, but animals generally require more training in comparative studies because they cannot be given verbal instructions and must learn procedures through trial and error. More important, the response tendencies of humans did not vary significantly over the final 50 trials, indicating that they had reached a stable plateau. Although it is possible that humans were learning at the conclusion of the experiment, note that 200 trials is sufficient for even some notoriously slow forms of learning, such as implicit learning (Reber, 1967) and multidimensional category learning (Ashby & Maddox, 1992).

Possible Origins of Cross-Species Differences

One might ask why pigeons adopted the optimal strategy if humans failed to do so. Did pigeons switch because they understood the problem, or because switching had been reinforced frequently? If the latter is true, then their responses ought to change if something other than switching is reinforced. Figure 3 shows data from an additional experiment by Herbranson and Schroeder (2010), in which the probabilities were reversed: In this experiment's version of the task, switching won one-third of the time and staying won two-thirds of the time. Again pigeons approximated the optimal strategy, though it now involved staying on virtually all trials. The

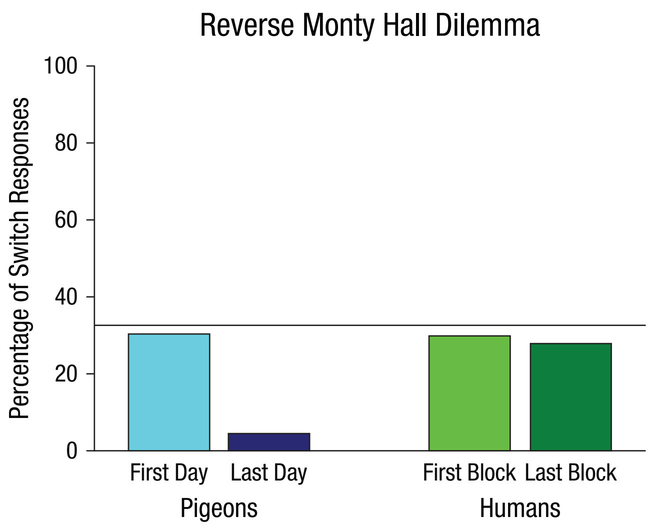

Fig. 3. Percentage of switch responses by pigeons and humans at the beginning and end of the experiment by Herbranson and Schroeder (2010). The line in the graph is at 33%, the probability of winning with a switch response. The optimal strategy is to stay on all trials.

human participants drifted toward the optimal solution, but they again fell short. Note that in both experiments, the proportion of switch responses by human participants approximately matched the probability of gaining reinforcement for switching. In the first experiment (Fig. 2), switching was reinforced two-thirds of the time, and human participants switched approximately two-thirds of the time. Similarly, in the second experiment (Fig. 3), switching was reinforced one-third of the time, and participants switched approximately one-third of the time.

Although their final response tendencies were different, both pigeons and humans behaved in ways that reflected the arranged probabilities. Pigeons maximized their potential payoffs by choosing the best response on virtually every trial. Humans, in contrast, matched their response tendencies to the probabilities of reinforcement—not an optimal strategy, but an indicator that they were sensitive to the probabilities in effect. On average, the probability of reinforcement for matching was only .55, compared with a probability of about .67 for the optimal strategy adopted by the pigeons. Probability matching is not unique to the Monty Hall Dilemma; it happens in many situations in which different responses have different probabilities of reinforcement (Herrnstein, 1997). One possible reason why people use probability matching is that they are searching for a strategy that will be correct 100% of the time, whether or not that level of accuracy can actually be attained (Fantino & Esfandiari, 2002). Thus, it may be the case that human participants seek a strategy that will allow them to exceed the reinforcement rate of 67%, even though no such strategy exists. The use of probability matching, then, might reflect not the lack of an optimal cognitive process but the presence of a suboptimal one: an active search that progresses even when there are no consistent patterns to be found (Gaissmaier & Schooler, 2008).

Although the asymmetry between humans and pigeons in these experiments is striking, the Monty Hall Dilemma is not unique in showing a cross-species difference in favor of pigeons. For example, research on mental rotation has revealed that compared with humans, pigeons rely on a more efficient process to identify objects at various orientations; this difference is presumably rooted in the differing ecological demands placed on flying birds and earth-bound humans (Hollard & Delius, 1982). The reasons for the interspecies difference in performance on the Monty Hall Dilemma are at this point unclear, but they might originate in strategies for optimal foraging in patchy environments (Charnov, 1976). An optimal forager will stay at one patch or switch to another on the basis of factors such as the richness of the environment and the energy required to move about. If the Monty Hall Dilemma draws on the same cognitive processes used in foraging, then animals from different ecological niches might be differently inclined to quickly adopt a switching strategy.

Why Are Humans So Consistently Fooled by the Monty Hall Dilemma?

The difference between pigeons' and humans' performance may reflect the fact that there is more than one way to solve the Monty Hall Dilemma (or any probability puzzle). Classical probability is an approach that involves an a priori analysis of the situation, as when one predicts that the chance of a coin landing heads-up is one in two. Note that no collection of data is necessary for this approach. Consequently, predictions based on classical probability are both immediate and precise (assuming a correct analysis of the problem). A second approach, empirical probability, involves collecting observations and making predictions based on the relative frequencies with which events have occurred in the past. Strategies based on empirical probability consequently take longer to learn than those based on classical probability and are subject to random fluctuations (especially in the short term). Despite these limitations, pigeons effectively used empirical probability to solve the Monty Hall Dilemma, as evidenced by the fact that their responses were random at the beginning of the experiment and changed as the pigeons gained experience, eventually settling on the optimal approach. Humans also learned from experience, but they fell short of the best strategy. Thus, they must have been using something other than (or in addition to) empirical probability.

Those other factors that lead humans astray might include heuristics and biases that clash with the Monty Hall Dilemma. For example, people are often subject to an equiprobability bias (Lecoutre, 1992). In the case of the Monty Hall Dilemma, this bias would correspond to the common but incorrect assumption that staying is just as likely to win as switching (an inaccurate implementation of classical probability). Even though it is erroneous in this context, the equiprobability bias is frequently useful in other situations, and it may be one of the common mathematical heuristics acquired during education. DeNeys (2006) found that university students generally believed that switching and staying were equally likely to win. This belief, however, was weaker among younger students than older ones, and only in the youngest group tested (eighth graders) did an appreciable number of students conclude that switching was the better strategy. The surprising implication is that education apparently makes the Monty Hall Dilemma harder, not easier.

The equiprobability bias, however, may just be the tip of the iceberg. Several other cognitive processes may interfere with the ability of humans to correctly solve the Monty Hall Dilemma. First, people may fall prey to an illusion of control (Langer, 1975). That is, people often believe they have an influence over random events. In the case of the Monty Hall Dilemma, they may believe that their initial selection is the most likely to be the winner. Given this assumption, staying is a more rational choice. Consistent with this hypothesis, Granberg and Dorr (1998) found that participants were more likely to switch when the initial choice had been made by someone else (though they still did not switch 100% of the time). Second, the use of suboptimal strategies in the Monty Hall Dilemma may be due to a failure of causal reasoning (Burns & Wieth, 2004). That is, humans may fail to acknowledge that an event (the host choosing to open one particular door) has two causes (the opened door is determined both by the host's initial placement of the prize and by the contestant's initial choice). When the problem is rephrased so that both causes are emphasized, performance improves. Third, people may hesitate to switch because they anticipate feeling greater regret if they were to switch away from the prize than if they were to stay with their initial selection and lose (Gilovich, Medvec, & Chen, 1995). Finally, humans often display base-rate neglect, whereby they fail to acknowledge the naturally occurring frequencies of events. Interestingly, Fantino, Kanevsky, and Charlton (2005) have shown that it is possible to train pigeons to commit base-rate neglect, which suggests that, given appropriate training, pigeons might be made to perform more like humans do on the Monty Hall Dilemma. Note that none of these possibilities are mutually exclusive. Considered together, they all converge on a common effect: failure to adopt the optimal strategy of consistently switching. The result is that the Monty Hall Dilemma is especially perplexing for humans. Avoidance of a single common bias or misunderstanding is not enough—one must dodge several in order to maximize the likelihood of winning.

Summary and Conclusions

Pigeons quickly and efficiently settle on the optimal strategy to solving the Monty Hall Dilemma, whereas humans do not. This behavior is particularly interesting when considered in conjunction with the recent finding that pigeons possess some elements of numerical competence that had previously been considered to be exclusive to primates (Scarf, Hayne, & Colombo, 2011). Pigeons presumably solve the Monty Hall Dilemma by observing the accumulated outcomes of completed trials and adjusting their responses accordingly. However, pigeons' statistical abilities are not infallible. Zentall (2011), for instance, has shown that in some cases, pigeons will prefer an option that has, on average, a lower probability of reinforcement, a suboptimal behavior that may parallel gambling in humans.

The striking difference between humans and pigeons on the Monty Hall Dilemma demonstrates the value of comparative psychology: Two species, when presented with the same problem, arrive at very different solutions. Those differences are not readily accounted for by general rules of learning, such as the law of effect (whereby behaviors that produce positive effects are more likely to be employed again). It is presumably the case, then, that some difference in the lifestyles or the evolutionary histories of humans and pigeons produces a corresponding difference between the strategies employed by the two species. It is the goal of comparative psychology to understand the nature and origins of such differences.

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Granberg, D. (1999). (See References). A cross-cultural investigation of the MHD, showing a suboptimal tendency to stay among students in four different countries.

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Zentall, T. R. (2011). (See References). A demonstration of strikingly suboptimal choice behavior by pigeons.

Declaration of Conflicting Interests

The author declared no conflict of interest with respect to the authorship or the publication of this article.

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